U.S. COAST GUARD

Autonomous Underwater Vehicles (AUV)s

A Look at Coast Guard Needs to Close Performance Gaps and Enhance Current Mission Performance

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Autonomous Underwater Vehicles (AUVs): A Look at Coast Guard Needs to Close Performance Gaps and Enhance Current Mission Performance

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Abstract

The Coast Guard has declared its intentions to exploit emerging technologies as it moves toward its vision of the Coast Guard in the year 2020—*Coast Guard 2020*. Attaining this vision requires appropriate integration of technology as part of the solution to close gaps in mission performance. For this to happen, the Coast Guard must make concerted and deliberate efforts to exploit technology, moving effectively from ideation through development, acquisition, implementation, and life-cycle support. The role of the Research and Development (R&D) Center in exploiting technology is to anticipate future needs, create ideas, and insert new technologies. As a platform for various sensors, the Autonomous Underwater Vehicle (AUV) is one such technology with the potential to close the gaps in Coast Guard performance as well as enhance current mission capabilities. This paper addresses Coast Guard's AUV needs for specific mission areas.

The variety and unique nature of Coast Guard missions add a high degree of complexity to technological solutions. In a world where high complexity often equals high cost, development does not always follow a path that resolves the issues encountered by the Coast Guard. By working to articulate its needs now, the Coast Guard hopes to influence AUV development in such a way that off-the-

shelf items eventually can meet its operational needs. Several areas show that AUV developments are already taking this path. AUV complexity can be addressed through the ever-reducing costs of computing ability, modularization, sensor packaging, communication networking, and miniaturization.

Background

The following mission areas are addressed in this paper:

- *Fisheries Management*: Enforcing fishing restrictions with a 24/7 presence, and detecting and identifying violators
- *Port Safety and Security*: Monitoring environmental and vessel traffic, and identifying polluters and pollutants
- *Law Enforcement*:
- Identifying and tracking suspect vessels for interdiction, possibly using acoustic monitoring

For each mission area, an AUV application is described that could meet Coast Guard needs for that particular mission. Concepts that are addressed include the following:

- Reliability of the sensor and platform. The AUV system's reliability is integral in determining its effectiveness. This reliability requirement cannot be stressed enough. The ocean is a harsh environment, and the Coast Guard operates in its worst conditions.
- Identification of potential benefits to the Coast Guard and the nature of that benefit. With an AUV system, the Coast Guard must save time, reduce costs, and/or be more effective in meeting its mission areas.
- Logistical support and costs for integration and use of an entire system. Topics to be considered include ease of operation, field repair complexity, support equipment, and personnel skills required to maintain the AUV system.
- Type, quality, and method of data transmission, such as two-way capabilities (for data dumps, alerts, and command overrides) and image capture above and below the surface. Considerations for verification of authenticity and source must be addressed.
- Deployment capabilities, methods of launch, time on-station, and obstacle avoidance. Deployment may be from different assets, such as aircraft, surface ships, small boats, and shore.
- Legal aspects for prosecution. Topics to be considered include accuracy, quality, and authentication of sensor data and position.

To be utilized by the Coast Guard (or by any organization), AUVs must meet the Coast Guard's missions and needs in an affordable manner. The potential benefits of using AUVs to enhance mission performance justify the Coast Guard's interest in current developments of AUV technology.

Recently, AUV technology is beginning to show major strides in the development of accessories and supportable systems. Looking at emerging AUV support technology such as communications and the resultant potential savings in asset time, personnel on-site, and fuel, AUVs become a very attractive mission tool. Concurrently, the Coast Guard demands extremely rigid performance requirements of any AUV.

Introduction

The Coast Guard is a small agency with broad responsibilities. This paper does not address every mission and identify shortcomings where AUVs could fill performance gaps. Rather, this paper examines some areas where the potential afforded by an AUV could make a significant difference in achieving mission goals.

This paper reviews three operational areas: fisheries management, port safety and security, and law enforcement. These areas have both overlapping and unique requirements, and each involves multiple missions. For instance, with port safety and security, the broad scope of the Coast Guard mission profile incorporates many things such as:

- Determining the environmental safety of a port
- Protecting against the likelihood of terrorist activity
- Preventing against the introduction of nonindigenous species being brought into port via ballast water exchanges
- Verifying that ships in port are seaworthy
- Validating cargo being transported through shipping lanes
- Determining which seasonal traffic considerations are in effect
- Verifying that shore facilities are operating safely
- Ensuring that sufficient and appropriate Coast Guard resources are available in case of an emergency
- Ensuring that all channels are correctly and adequately marked

It is understood that there will not be an all-inclusive AUV to conduct all Coast Guard missions. Instead, the Coast Guard requires a combination of characteristics and capabilities that will make an AUV the better alternative to current operating methods.

Up-front logistical costs that go far beyond the cost of the equipment itself are important considerations for determining AUV use in Coast Guard missions. If AUVs are to become Coast Guard assets, the service must account for how the AUVs are to be used, where they will be stored, what kind of training is required, what maintenance is required, and what support system is needed.

This paper also addresses other key topics such as standardization requirements, modularization, miniaturization, and ease of operation. For instance, it would be advantageous to have one generic navigation system, but could one system handle the diversity of Coast Guard missions? Many missions would favor a small, very portable AUV, but could that same AUV carry the required sensor packages? AUVs with greater flexibility, modular subsystems, and reconfigurable sensor package systems are key to the Coast Guard's decision to change its way of doing business and make AUV capabilities part of standard operating procedures.

Mission Overviews

The following subsections are more detailed requirements of Coast Guard missions where there is potential for AUV applications to improve Coast Guard mission performance.

Fisheries Management

The Coast Guard is tasked with the guardianship of the offshore Living Marine Resources (LMRs). These are ocean areas where commercial fishing is restricted or banned. Cutters are sent to

patrol these areas, typically for 2-week periods, to ensure that there is no illegal activity. Methods of enforcement involve activities such as multiple boardings with inspections, covertly blending in with a fishing fleet at night, high-altitude aerial reconnaissance, and long-rang radar detection. Typical cutters patrolling the restricted or closed fishing areas are big and white. While the cutter is on-site, the fishermen will fish just on the outskirts of the restricted areas staying in legal territorial seas.

Offshore Living Marine Resource

The effectiveness of Coast Guard enforcement efforts on this mission is only guaranteed while there is an on-site presence. The Coast Guard's ability to maintain this presence is minimal. Restricted/closed areas are often hundreds of square miles. The Coast Guard's ability to traverse, conduct surveillance, and intercept illegal fishing vessels in these areas is limited because of too few assets, people, or equipment. The result is a methodology that cannot meet the mission goal, which is to protect these areas against depletion of fish stocks.

How could AUVs potentially improve the Coast Guard's effectiveness in missions such as this? Autonomously operated AUVs, coupled with various technologies to detect illegal activity and/or sort/classify targets of interest (e.g., night-vision optics/photography, FLIR, long-range radar, SOSUS, VMS), may provide the cost-effective, 24/7 platform to cover large restricted areas effectively. These AUVs, however, could not provide an effective deterrent superior to the current method of having an on-scene cutter.

An AUV could not conduct boardings, which is fairly substantial in terms of capability. First, with "prosecutable" being the key word, could an AUV obtain prosecutable evidence? Prosecutable evidence requires quality information of proven accuracy, reliability, and authentication. An example of prosecutable evidence is real-time video of a vessel engaged in illegal fishing: the video must show an identifiable vessel in a specific location clearly engaging in the specific illegal activity. This prosecutable evidence requires quality image capture, own-ship positioning capability, and established range and distance from the AUV.

Second, assuming the AUV could obtain prosecutable evidence, the AUV must communicate the data to an interested party, which requires remote transmission of data such as video, still pictures, recordings, and position data. A simpler transmission option is an alert for a vessel to be dispatched to download the data; however, this requires the AUV to verify the data and their quality onboard prior to having an asset dispatched for download.

Third, assuming that the AUV could collect evidentiary quality data and transmit them to an interested party, the AUV must get to a position to use these capabilities, which requires the AUV to perform a series of complex maneuvers. These maneuvers include detecting a

target, moving to a position where the AUV could gather the required information, providing an alert or direct data transmission, and perhaps relocating to a preferred download location. A properly programmed, high-speed, long-duration AUV, or multiple networked AUVs, could accomplish these maneuvers. Because of the size of many restricted areas, the multiple AUV option would likely be the most practical option.

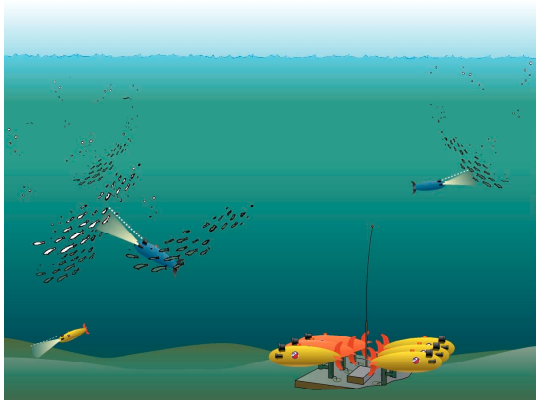
Finally, assuming all criteria are met, there is no advantage to an AUV system instead of current operating methods unless on-site presence is measured in months rather than days. With an increased effective presence, the AUV becomes the more suitable, viable option. Based on currently available power supplies, the AUV would most likely require a recharging or base-station type configuration. The number of stations would be determined by the range capabilities and mission requirements of the AUV after a single charging. The logistical aspect of deploying base stations would not be difficult for the Coast Guard as it is fully equipped through the Aids to Navigation program. Multiple units and base stations, however, do affect cost.

In deploying a multiple AUV system with a recharge station, the AUVs patrol the restricted area and listen for targets of interest. A target is detected, and one of the vehicles moves to an appropriate monitoring position based on sensor capability. The AUV captures an illegal activity on video and sends it to a desktop computer along with the position data. Three days later, the fishing vessel pulls into port to sell its catch, and the appropriate authorities meet the vessel at the dock to confiscate its catch. The added benefit is that other fishermen then assume that they are being watch at all times by new Coast Guard minisubs.

Some additional questions will affect AUV capabilities if a system is to be used more than once. How covert is the data gathering process, and does the sensor that is gathering the prosecutable evidence have a range greater than its counterdetection range? It is likely that detected AUVs will be targeted. Up to what sea state does the AUV system operate effectively? If the suspect vessel knows that data quality is compromised by heavier sea states, it may adjust operations to fish in rougher weather. Does the system have a night capability, and if so, what does it cost? If everything operates as designed, what is the optimal number of vehicles for reasonable effectiveness? When all these questions are considered, the AUV system begins to take on some substantial costs.

An alternative option to alleviate some escalating costs is interagency cooperation. Instead of the Coast Guard assuming the full cost of a single-purpose system with all the “extras,” why not launch a system that fulfils the needs of multiple agencies? Partnering with NOAA Fisheries, local fisheries councils, the National Science Foundation, and universities, an AUV system could track all activity in the area of concern. Fish counts could be made, bathometric information gathered, ocean bottom

samples analyzed, and any number



Multi-Unit Cooperative Effort Concept

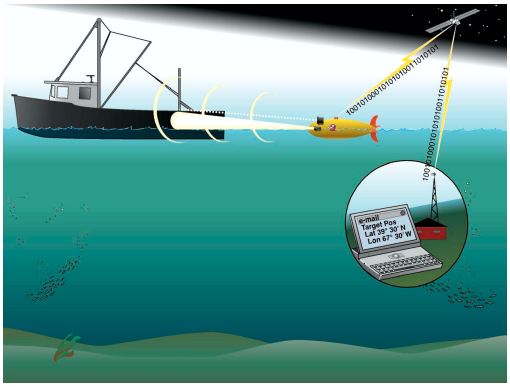
of species watched. When activated, the Coast Guard's protection units would be deployed to gather their law enforcement-related data.

The participating agencies would share all costs of operating the base station and maintaining the system. This cooperative effort would provide the means for better understanding of restricted areas and allowing the Coast Guard to maintain a full-time presence to ensure the integrity of these areas.

A variant of this mission is patrolling a vessel exclusion area, which is where an automated Coast Guard presence would be beneficial. In this situation, the Coast Guard has regularly scheduled patrols, often aerial, over parts of the ocean where there should be no vessel traffic. The advantage that an AUV would offer is that one or more AUVs could be sent to cover a given geographic area. The AUVs essentially would park and listen.

A possible configuration here is a self-recharging AUV. With the proper positioning capability, the AUV is dispatched from shore to its assigned area of surveillance, moving to an appropriate depth to monitor vessel traffic. The target of interest is any vessel, making the identification programming aspect simpler. When the AUV needs recharging, it rises to the surface, establishes its position, checks for instructions via satellite, and recharges with solar panels. When it is recharged, the AUV relocates to the appropriate area to continue its mission.

When activated by suspect vessel traffic, the AUV rises to the surface and reports its position and targeting data to an interested party. A Coast Guard asset is dispatched for reconnaissance only when vessel traffic is reported. This is when there is potential to save substantial Coast Guard asset time by responding only when there was a violation in progress instead of a weekly or daily patrol.



Target of Interest Alert

Port Safety and Security

Port safety and security is a Coast Guard mission that involves many operational aspects. The Coast Guard has an environmental responsibility to the ports including shoreside facilities. This responsibility extends to traffic management, Aids to Navigation, health or safety of the port, quantity and type of cargoes traversing the port, seasonal changes in traffic (especially with regard to pleasure boating traffic), and the

possible threat from weapons of mass destruction.

One problem frequently encountered in port by Coast Guard Marine Safety Offices (MSOs) is the elusive "mystery sheen." A mystery sheen is oil- or gas-like coloring in the water that has been spotted and reported to the Coast Guard. The source of these sheens typically is bilge pumped from a vessel in port. With a membership approximately the size of the New York City police force and an area of responsibility of U.S. coastal waters, the Coast Guard cannot be in all places at all times, which is a common problem with any law enforcement activity. It also is exploited effectively in various ways, with the result being that the source of a mystery sheen remains just that, a mystery.

For example, in a port with an active shrimp fleet, the main fleet dock is located approximately 1 hour from the MSO. According to the MSO, the fleet produces a mystery sheen three to five times a week. The MSO is not equipped to maintain a watch on the fleet at all times, and relies on reports of sheens on the water. Typically, the MSO receives a call about a sheen in the evening. Since the MSO is 1 hour away from the reported sheen, the MSO arrives at the site to find that (1) the sheen has dissipated and cannot be sampled effectively, or (2) there is insufficient daylight to locate the reported sheen. As a result, the typical MSO response is to log the report and take no other action.

With the proper application of AUV technology, this situation is resolved differently. Since the area of the sheens is well known and the time of the sheens is fairly constant, an AUV located close to that area could conduct preprogrammed search patterns at preprogrammed times using an onboard analyzer to fingerprint the sheen. If the AUV sufficiently samples to obtain a fingerprint, it notifies the MSO. At a convenient time soon after, the MSO dispatches someone to sample bilges and identify the source of the encountered sheen for appropriate action. This deployment may not guarantee results, however, because of the transient nature of the sheens.

Remote Identification of Mystery Sheen

A more reliable yet more complex solution is to have a trigger for the search. Following the report of a sheen, a passing vessel or a signal from the MSO triggers an AUV to its sampling mission. This trigger option depends on how the sheen is believed to be caused, such as pumping bilge on the way into port or cleaning once docked. This option also requires a two-way communications system, such as a shore-connected charging station (but this may compromise the covertness of the operation).

The covertness of the operation has its benefits: when a successful, no one saw the vehicle take the sample, so everyone believes the vehicle is still out there. One AUV can then be moved and/or rotated through several areas of interest, thus enhancing the ever-desirable cost-reducing aspects of this system.

A complication of this system is that navigation must address collision avoidance, which would be carried out in areas where there is (potentially) high boat traffic. Collision avoidance requires sophisticated navigational capabilities.

A similar thought along a slightly different vein is to develop an AUV with a longer operational duration. The AUV could then be launched from or based at a Coast Guard station and sent to patrol the port looking for chemical abnormalities. The patrol route could be varied and/or based on calls. Navigation could have sensor inputs allowing the AUV to track the pollutant to its source.

Chemical Detection to Source

These applications would require navigational programming that is extremely user friendly, which could complicate the navigation program. This consideration is especially important in the initial stages of AUV development. If the first few AUVs are too difficult to use, require too much specialized training, and too narrow a purpose, then the concept of Coast Guard AUV fleet may not come to fruition.

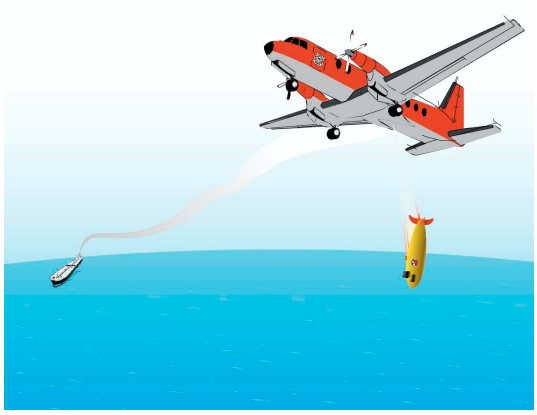
Law Enforcement

The law enforcement mission involves detection, identification, tracking and interdiction of suspect vessels. The Coast Guard could use a force multiplier in detecting and tracking, especially in large areas of operation. In many instances, Coast Guard assets could be better deployed because of the kind of intelligence offered by the AUV. In this mission area, the AUVs offer covert reconnaissance with the option of mobility. Similar to the fisheries management mission, once the AUV detects a target of interest, the AUV then reports the contact to an interested party, which is sufficient capability for the AUV on some law enforcement operations with the Coast Guard sending a manned asset to conduct the actual intervention. The savings occur when manned assets are only deployed when there is a need. Therefore, the purpose of the AUV would be to increase the ratio of patrol time to successful interdictions.

Patrolling an area without intelligence on suspect activity and looking for a specific target of interest are less than optimal. Patrolling an area of known trafficking yields some positive results. Going to an area of an identified target of interest likely yields better results. At the very least, using the AUV to extend the sensor range of the patrol boat could increase the number of interdictions.

With GO FAST targets, it is unlikely that the Coast Guard would use an AUV to identify and track the target since it typically runs at speeds in excess of 30 knots. However, it would be useful to deploy an AUV system that could identify the location and course of a GO FAST so that it can be intercepted. A system of multiple AUVs deployed across a large area illustrates the picket fence concept. Many factors, such as sensor range and communications set-up, determine the spacing and number of

AUVs. A buoy system could be used for the picket fence concept, but AUVs offer the advantage of mobility. With mobility, the AUV system could be put on a patrol pattern so that one sensor now covers twice the area in half the time. If the AUV system has positioning, targeting, and communications, then the GO FAST would be reported by location and direction. With the proper spacing of your AUV fences, the area of re-acquisition decreases substantially, allowing for far more productive patrol time for Coast Guard assets.

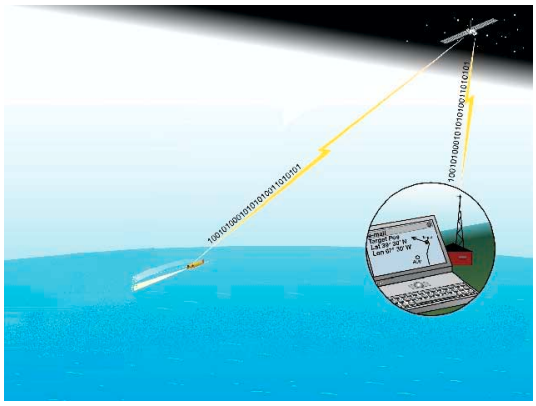


Tracking and Reporting on GO FAST Activity

Unlike the buoy system, the entire AUV system can be moved easily to a new area of operation. The AUVs could be sent a message to move to another area or simply be recalled for pick-up and transfer. Even if the AUV system is utilizing a base station for recharging, it is conceivable that the base station could be designed to move to a new location using its own AUVs.

The detection of the GO FAST would not be as difficult as the identification of a specific fishing vessel. With the fishing vessel the AUV gathers prosecutable evidence. With GO FAST, the Coast Guard only needs to know that there is a high-speed vessel transiting a certain location in a specific direction, as the interception would be by a more traditional asset. Similar to the fisheries management mission, AUV potential increases with on-station time. To go to an area of interest and maintain watch for months are highly desirable capabilities. These capabilities combined with a networked multiple-vehicle system give the Coast Guard a covert, movable, picket fence that detects and reports on activity of interest.

While GO FAST interception requires AUVs to be detectors and trackers, there are law enforcement applications that require both tracking and trailing capabilities. In the Pacific area of operations, a suspect vessel may be found only to be lost while an asset returns for refueling. This is not atypical where the areas being patrolled exceed thousands of square miles. Here an air-dropped AUV could be deployed if it had the endurance and speed to maintain contact with the suspect vessel. Reporting back position data in the process of tracking allows for better allocation of existing resource time. With an adequate mission time capability, the AUV would be the only asset needed.



Air-Deployed Tracking AUV

Summary of Coast Guard Needs for Future AUV Capabilities

What is the Coast Guard looking for in an AUV? The Coast Guard is in the process of defining the future capabilities of its deepwater fleet. Are AUVs going to be an integral part of this procurement? If they are, what capabilities will be required? The previous scenarios are speculative and require capabilities that currently do not coexist in any single AUV. At this time, the Coast Guard hopes to work with other agencies in developing the technology for future procurement of this type of asset.

For AUV technology to be of real value to the Coast Guard, there are many capabilities that need to be addressed:

- One of the most important capabilities is mission time, specifically autonomous mission time. There is limited application within the Coast Guard for an AUV with only a 12- to 48-hour mission time. Whether this is extended through the use of recharge stations or through alternative power sources, mission time must be measured in months, if not years.
- Navigational capabilities must be user friendly and very versatile. The Coast Guard will be looking for a single navigation program that minimizes the training time required to use it.
- Basic AUV construction and subsystems require some sort of modularity so as to facilitate field repairs and minimize mission downtime.
- The AUVs must be capable of handling two-way communications and data transfer to remote locations. The range of data will include still images, video imaging, and instrument/sensor data, and may even be extended to support encrypted data.
- Data quality must be very high, and losses in transmission must be almost nonexistent.
- AUVs must be able to be networked, not only with each other but also with other Coast Guard assets (planes, helicopters, ships, and small boats).
- AUVs must have precise positioning and targeting capabilities. The level of precision must stand up to the scrutiny of a court of law.
- For some applications, the AUV's top end speed must be increased. While some AUVs exist with impressive speeds, this is not the norm and usually precludes submergence or extended mission time.
- The units must handle a variety of instruments and sensors. Current efforts at miniaturization are yielding some very usable equipment.
- The units must be handled with ease, such as with a specialized launch platform or a small size. Small size lends itself to more versatility thus wider application, but this needs to be examined in conjunction with the tradeoffs of payload and power capabilities.
- Another important aspect in the design of a future Coast Guard AUV is the logistical support required to maintain a fleet of AUVs. Logistical support includes spare replacement parts, failure rates, and required abilities to affect repairs. It needs to be kept simple or be a subcontracted service.
- Finally, AUVs must be cost effective, but this is not to say inexpensive or cheap. The cost of the AUV system must be justified by its capabilities. All aspects of the cost must be considered including unit cost, system cost, integration cost, training cost, and entire life-cycle costs.

Conclusions

The Coast Guard is new to the world of AUVs, entering this arena in the hopes that development can be influenced to meet operational needs. The Coast Guard is committed to partnering with agencies and institutions that have similar operational needs and financial capabilities to advance AUV development and technology. The Coast Guard has a wealth of experience with the marine environment and the assets and applications to demonstrate and effectively test the potential of AUVs. The Coast Guard is always looking for ways to accomplish its missions more efficiently and more effectively. The Coast Guard believes it can benefit greatly from automation in many of its mission areas. Fully capable AUVs have the potential to yield these benefits for the Coast Guard.

When you've built it for the Coast Guard, it will serve the world!